Declines in age and size of upper Willamette River spring Chinook salmon

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After seeing the titles from some of the other talks, I realized that I'm the only one to report my findings in my title, perhaps making me the worst poker player at the conference. Nevertheless, I'll be discussing trends in age and fork length or spring Chinook from the upper Willamette River, focusing on coded wired tag data from hatchery fish.

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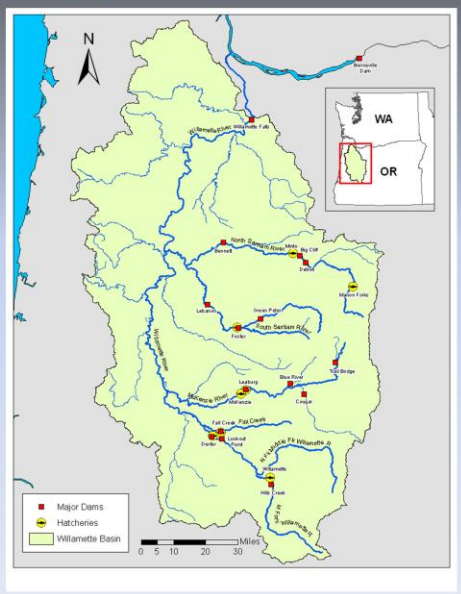
Upper Willamette R. Spring Chinook



Four ChS Hatcheries
- Marion Forks (N.Santiam)
- South Santiam
- McKenzie
- Willamette (MF Willamette)

Conduct 1:1 random matings

Jacks typically <5% of broodstock

~6 million smolts/year

Now, most of you are familiar with the upper Willamette basin, pictured her and defined by the portion of the basin above Willamette Falls. There are four spring Chinook hatcheries in the basin, Marion Forks Hatchery (on the North Santiam), as well as South Santiam Hatchery, McKenzie Hatchery and Willamette Hatchery, on the Middle Fork. Altogether, these facilities produce and release approximately 6 million smolts. During spawning, single males are randomly paired with single females, and jacks are also included in the broodstock, though they typically represent less than 5% of the population.

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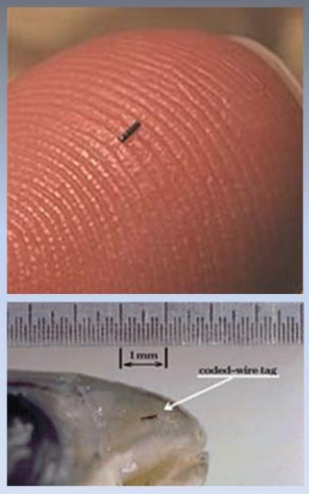
Coded-wire Tags (CWTs)



Photos courtesy USFWS

~690,000 tagged smolts released annually

CWT recoveries:

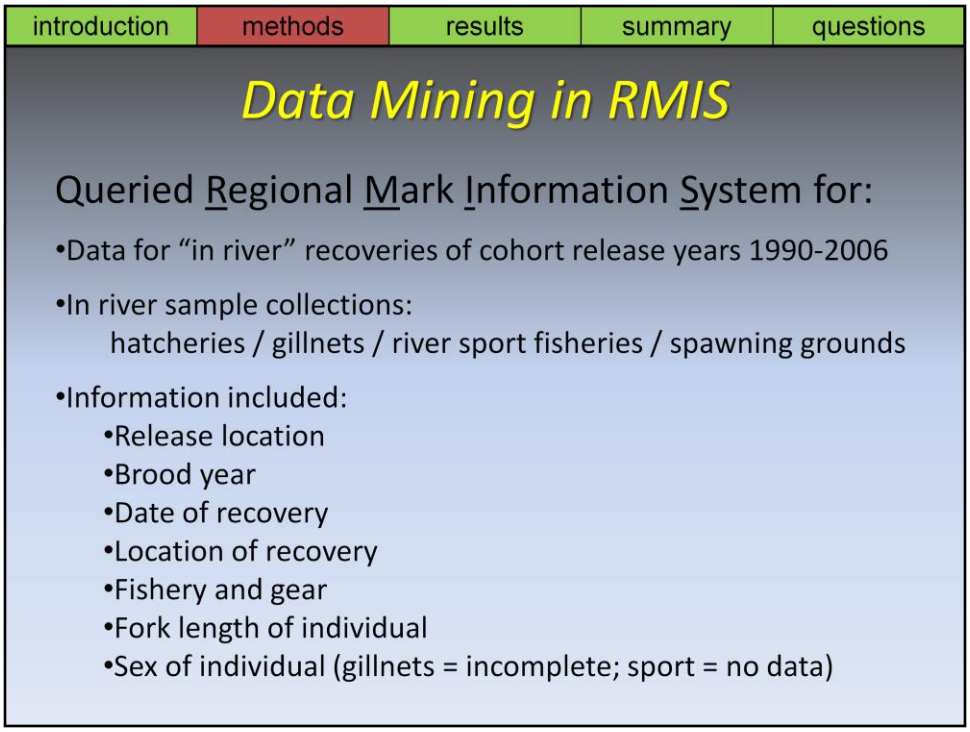
65% Hatcheries
11% Lower Columbia R. gillnets
10% River sport fisheries
3% Spawning grounds
11% Ocean fisheries and "Other"

Do CWT data suggest trends in
1) age at maturity?
2) size (fork length) at maturity?

Each year, approximately 700,000 smolts from these hatcheries receive coded-wire tags prior to their release. Tagged adult fish are typically recovered years later when they return back to the hatchery, though significant numbers of tags are also collected through Columbia River gillnet fisheries, Willamette and Columbia river sport fisheries, spawning ground surveys or ocean fisheries, scientific trawls and the like.

Important to note here is that almost 90% of recoveries are in river…and can tell us something about mature adults as they return to spawn.

So, knowing this, I asked the question, "Do coded-wire tag data suggest trends in age or size at maturity?"



To address this question, I first queried the Regional Mark Information System for in river recoveries of upper Willamette River spring Chinook that had been released as juveniles between 1990 and 2006. The information that I obtained for each recovery included the release location, brood year, date of recovery, location of recovery, fishery and gear used, the fork length…well, the truth is that I downloaded all of the available information: It's free.

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Lower Columbia R. Netpen Releases

Only fish released in UWR basin
(No SAFE Program* releases)

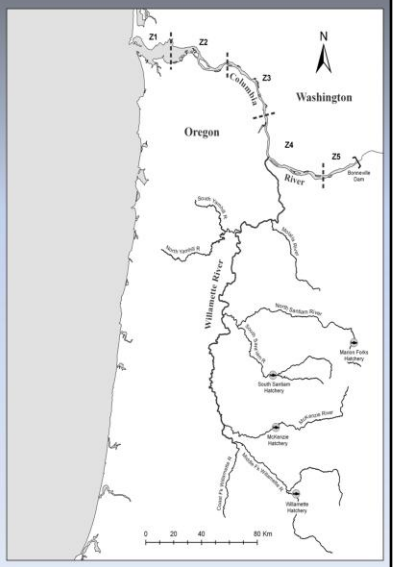
<u>Gillnet samples</u>

Only from commercial netzones 1-5
(No SAFE Program harvest recoveries)

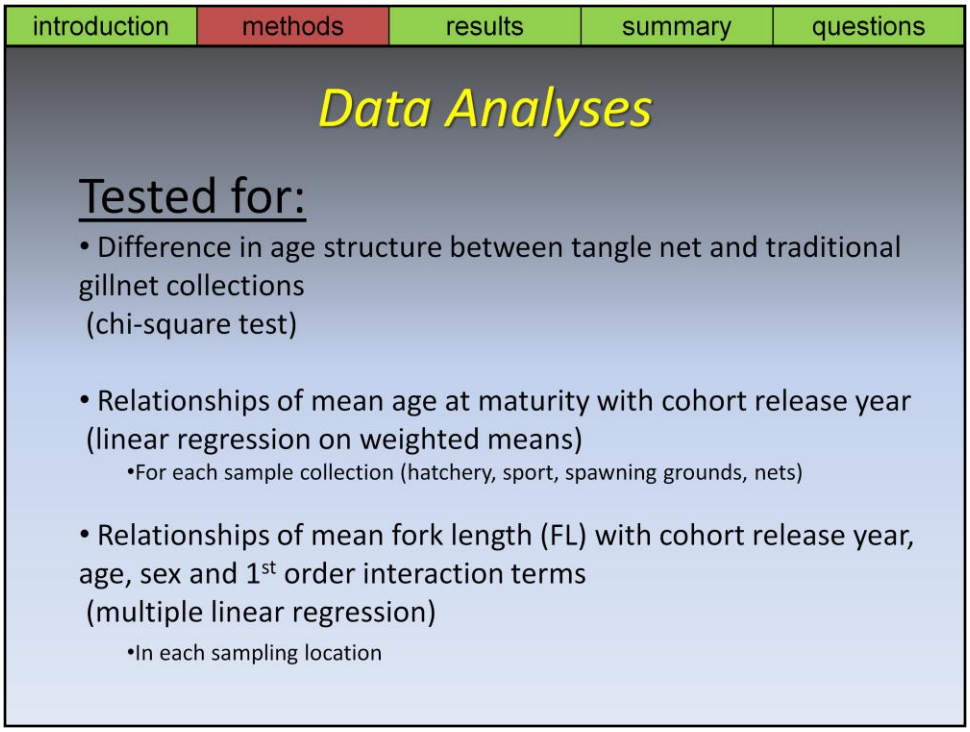
Recovery dates identified gear type

Traditional gillnets (8-9 in. mesh)
vs.
Tangle nets (4 ¼-5 ½ in. mesh)

*Select Area Fisheries Enhancement Program



A few quick notes about samples collected with gillnets. First, I should emphasize that we only analyzed data for Chinook released in the upper Willamette River basin, so we did not include data for fish released from netpens through the SAFE Program. We also didn't include fish that were harvested through the SAFE program by only using samples collected in Columbia River netzones 1 through 5. Finally, for fish that were harvested in these zones, we were able to use the collection date to determine which kind of net had been used, either large mesh traditional nets or small mesh tangle nets, since traditional and tangle nets are never used simultaneously.



Then, using data from recovered coded wire tags, I performed a chi-square test to compare age structures of Chinook taken with traditional gillnets and tangle nets.
I then calculated the mean age at maturity of each cohort in each sample collection; and used linear regression analyses to test for relationships between release year and mean age at maturity, weighted by the sample size of recoveries for each cohort
I then used multiple linear regression to test for relationships between cohort release year and mean fork length, while accounting for the effects of sex and age on fork length

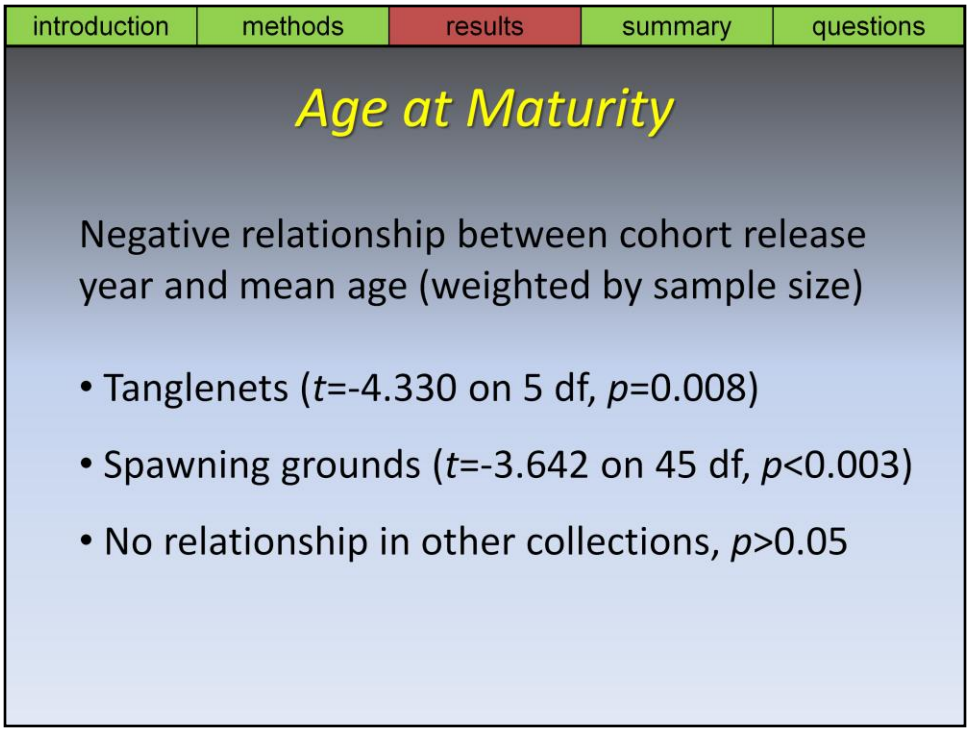
Age: Tangle Nets vs. Traditional

Age structures different between tangle and traditional gillnets (χ^2=28.004 on 2 df, p<0.001)*

	Age 3	Age 4	Age 5	Age 6
Traditional	0 (0%)	19 (6%)	270 (89%)	14 (5%)
Tangle Net	1 (0%)	180 (12%)	1256 (87%)	15 (1%)

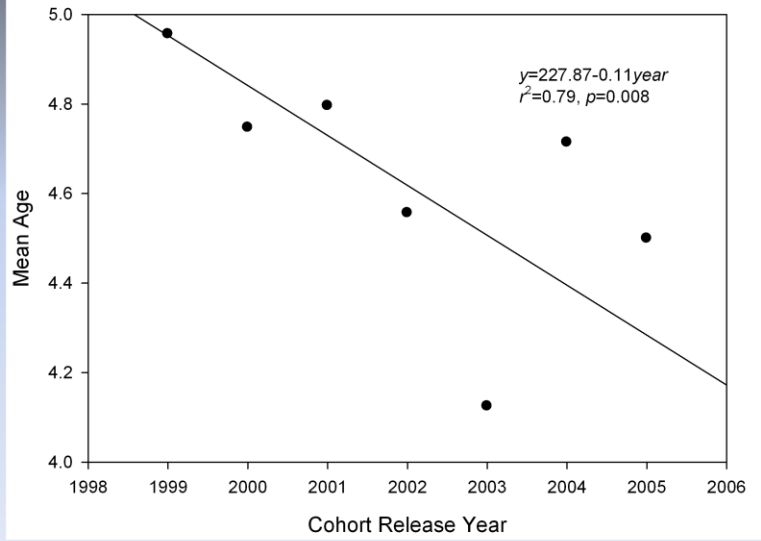
*Data from run years 2002-2009, when both gear types were used

Moving now into results. I found that the age structure of Chinook taken with tangle nets was significantly different from traditional gillnets, with a higher percentage of age 6 and lower percentage of age 4 fish harvested with traditional nets. So, knowing this, I evaluated the effect of cohort year on mean age and fork length separately for tangle nets and traditional nets. Of course the other thing we can't ignore is that both net types really target 5 year old Chinook…with nearly 90% of the catch being 5 year olds in both net types.



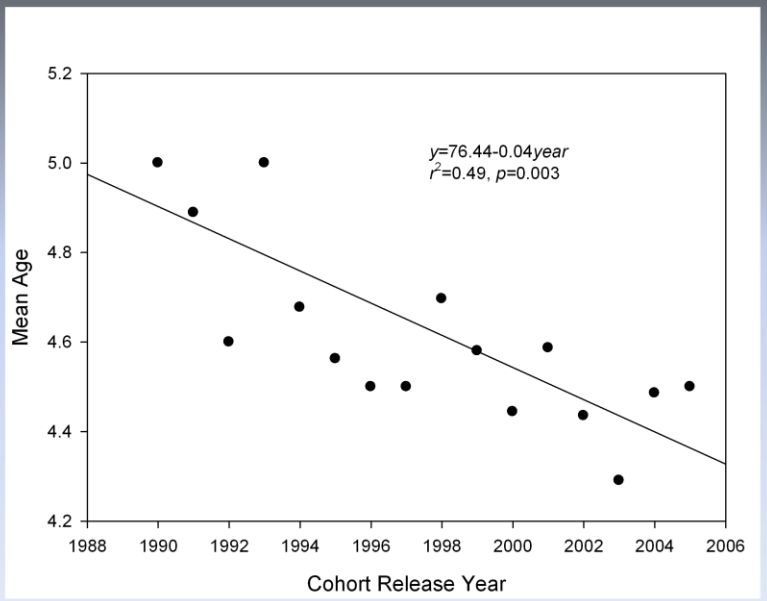
Interestingly, we found evidence for declines in mean age at maturation in samples collected from tangle nets and spawning grounds, but not in other sample collections

Age at Maturity: Tangle Nets

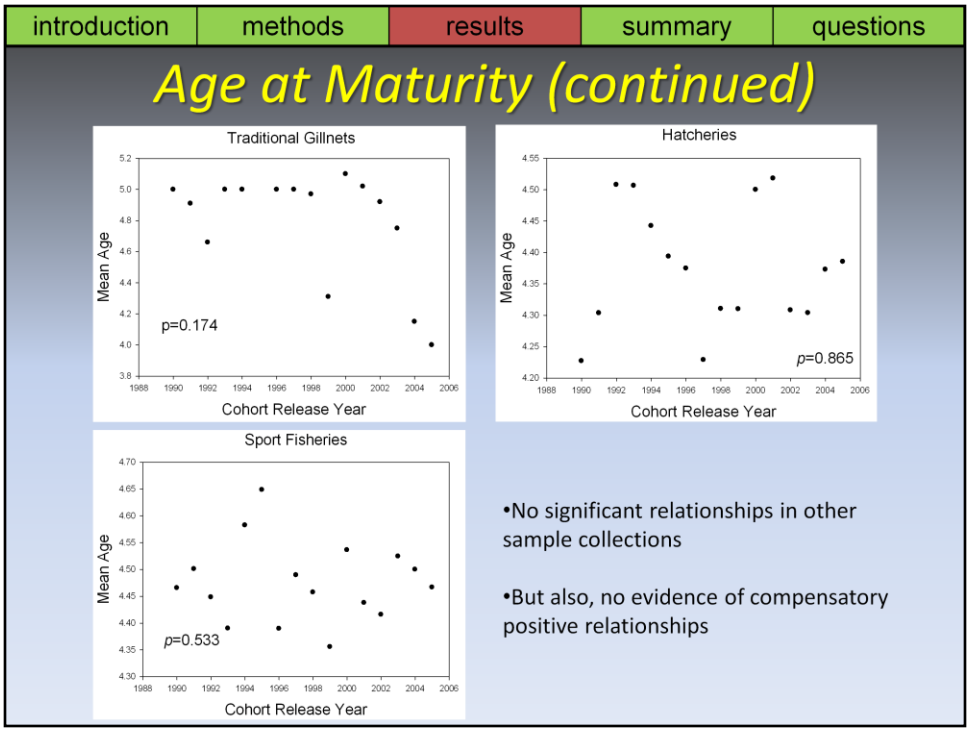


Here I've plotted mean age at maturity against cohort release year for sample collected with tangle nets and, as you can see, mean age has shifted from 5 year olds to 4 year oldsover this time period

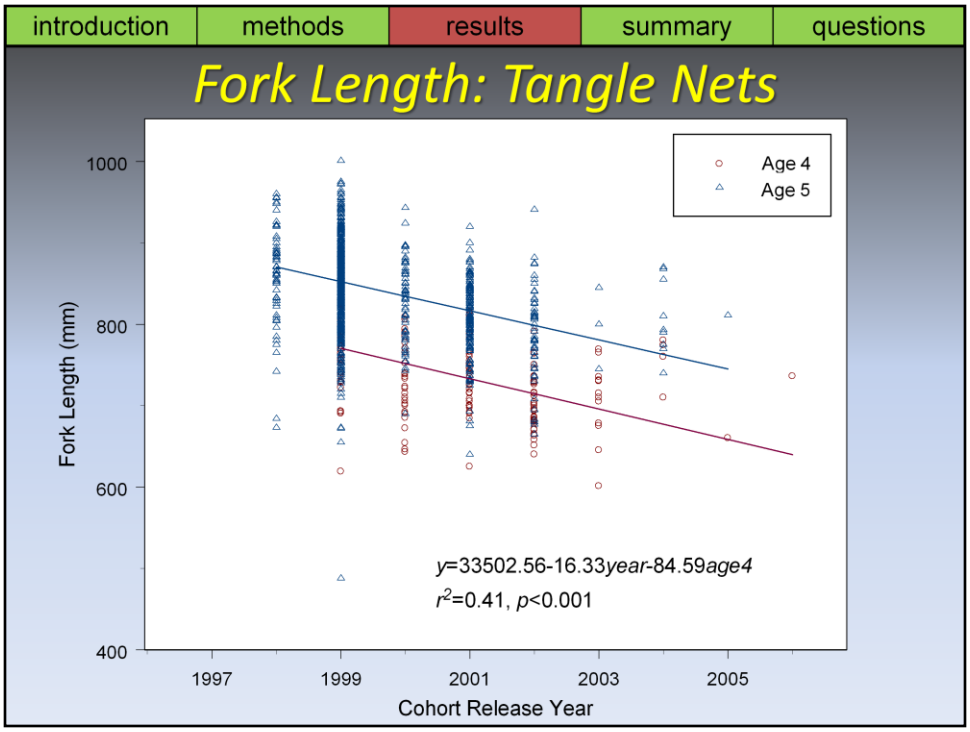
Age at Maturity: Spawning Grounds



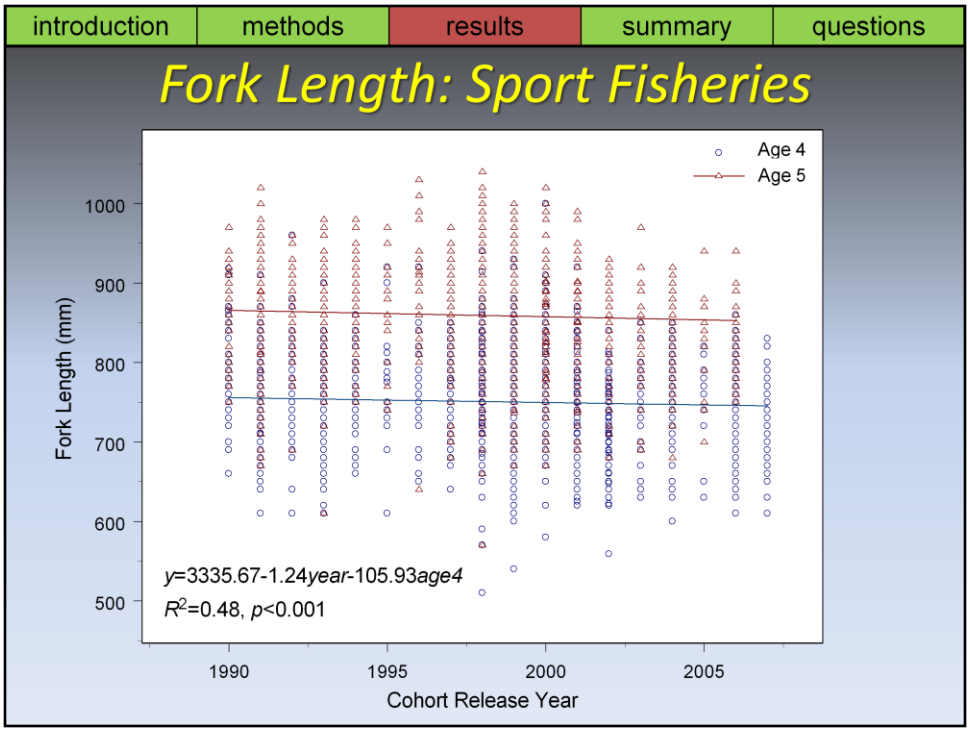
Samples from spawning grounds reflect a very similar pattern. So, the question arises, "if these patterns are real, why don't we see evidence for them in sport fisheries, traditional gillnets or hatchery samples?"….ideas



And just to have a look at those data, here we have mean age at maturity in traditional gillnets, hatcheries and sport fisheries. Now, a point worth noting is that although we don't see significant downward trends, we also don't see upward trends that might compensate for the declines in mean age observed in other collections.



Moving now to trends in fork length: As with mean age, we found evidence for downward trend in fork length for Chinook taken with tangle nets, after accounting for the variance associated with age…and here I should point out that I'm only looking at age 4 and age 5 Chinook…we just have very few samples for age 3 fish

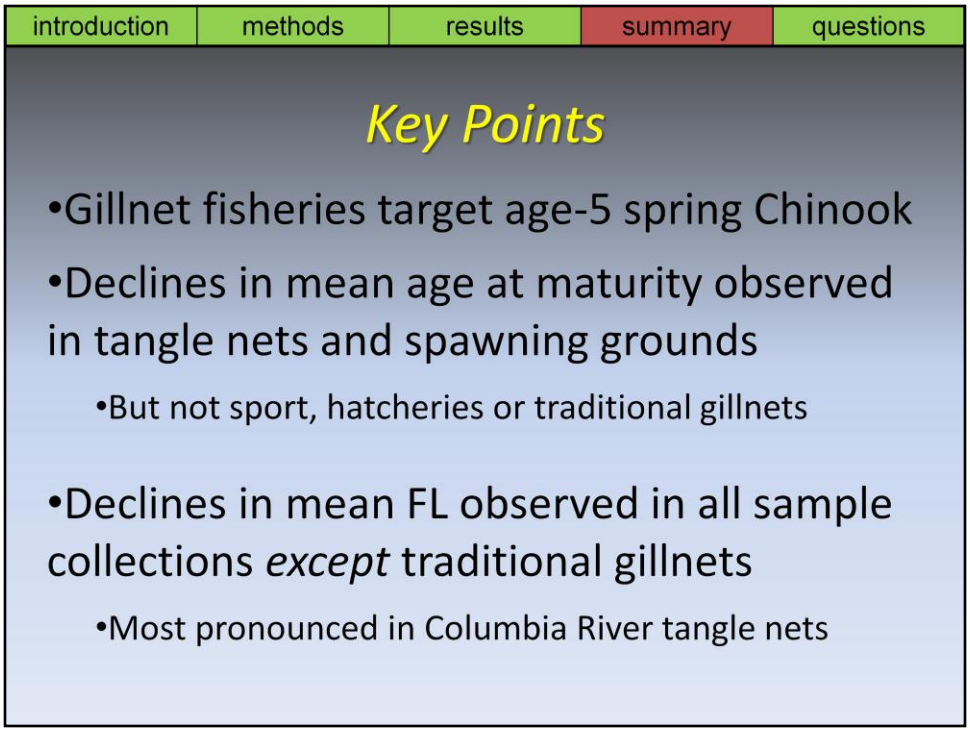


The data from sport fisheries are perhaps much less compelling, but here too, there is a statistically significant decline mean fork length over time.

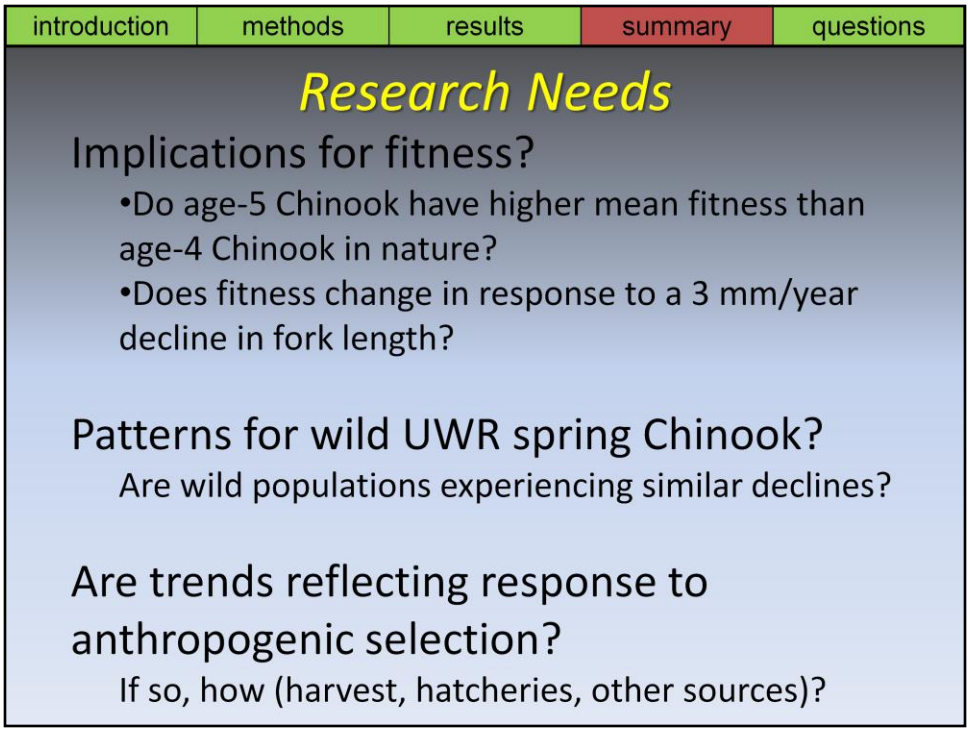
FL: Spawning Grounds and Hatcheries

Sample collection (model R^2)	Variable	Coefficient	SE	*t*-statistic	*p*-value
Spawning Grounds (R^2=0.355)	(Intercept)	7025.654	1845.395	3.807	<0.001
	year	-3.069	0.923	-3.324	<0.001
	age4	-106.776	3.669	-29.104	<0.001
	female	-21.411	3.809	-5.621	<0.001
Hatcheries (R^2=0.442)	(Intercept)	5275.040	378.471	13.938	<0.001
	year	-2.215	0.189	-11.696	<0.001
	age4	-1928.810	395.154	-4.881	<0.001
	female	-1704.400	379.260	-4.494	<0.001
	year×age4	0.914	0.198	4.621	<0.001
	year×female	0.856	0.190	4.509	<0.001

In fact, we found evidence of this decline in all sample collections except traditional gillnets. Data from spawning grounds suggested a decline of 3 mm per year. Similarly, age 5 male at hatcheries declined by just over 2 mm per year, but regression slopes for females and four year olds were than for males and 5 year olds, suggesting little change in length for age 4 females.



So just to briefly summarize, we found that gillnets tend to target age 5 Chinook, and this seems like a likely source of selection on age at maturity, though we certainly can't rule out other mechanisms. For example, random matings at hatcheries could confer greater fitness to 4 year olds than they'd typically achieve in nature.
We found significant evidence for declining age at maturity from tangle nets and spawning grounds samples, but this pattern wasn't observed in sport fisheries, hatcheries or traditional gillnets. Now, each of these collection methods obviously comes with it's own source of bias: for example, large mesh gillnets simply are effective at catching small, young Chinook.
Nevertheless, we found evidence for declining fork length in all sample collections except traditional gillnets, suggesting that this a very real, albeit subtle phenomenon taking place.



These findings raise a number of questions. For example, we'd like to know if the patterns we've found are actually translating into fitness differences. Do age 4 Chinook have significantly lower fitness than age 5 fish? And can subtle declines in size be expected to effect fitness?

We also need more information on wild populations. We might hope that the processes affecting hatchery fish aren't influencing wild populations, but with genetic introgression from stray hatchery fish, this probably isn't the case. Also, wild Chinook are as susceptible as hatchery fish to "fishing up" effects in ocean harvest.

And finally, at the most fundamental level, I think we need to identify whether these trends are actually a response to anthropogenic selection, and if so, from which sources(?).

And with that, I'd be happy to take your questions.

Acknowledgements

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Questions?